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(54) **BRAKE CONTROL SYSTEM COMPRISING
TIRE/RUNWAY FRICTION PROPERTY
ESTIMATION MAPPING**

(58) **Field of Classification Search**
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See application file for complete search history.

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Extended European Search Report dated Oct. 31, 2014 in European
Application No. 14171610.0.

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(51) **Int. Cl.**

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| G01L 5/28 | (2006.01) |

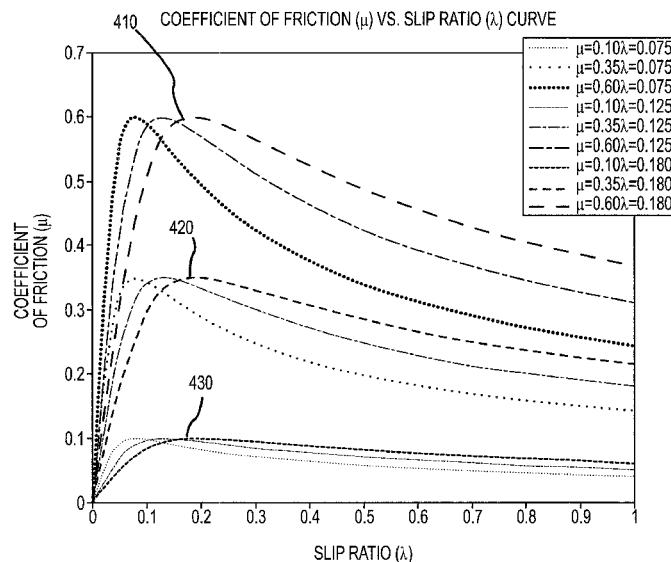
(57) **ABSTRACT**

Systems and methods for a tire/runway friction property estimation method based on measured wheel speed, calculated acceleration, wheel reference and tire normal force estimation are disclosed. Based on the resulting estimations, a map and/or function of position for the friction properties may be formed and transmitted to external systems after an aircraft stop is completed.

(52) **U.S. Cl.**

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19 Claims, 5 Drawing Sheets



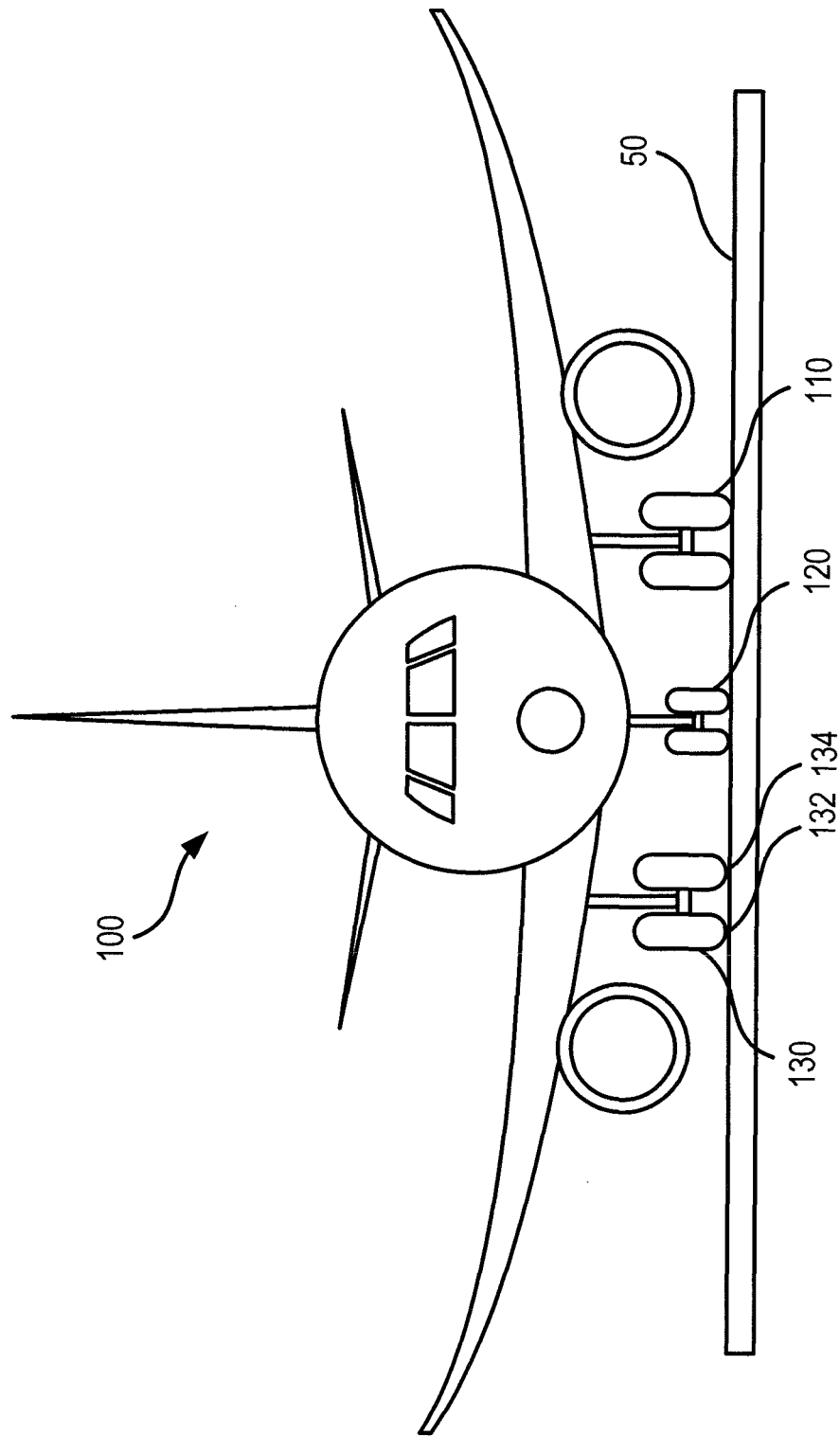


FIG. 1

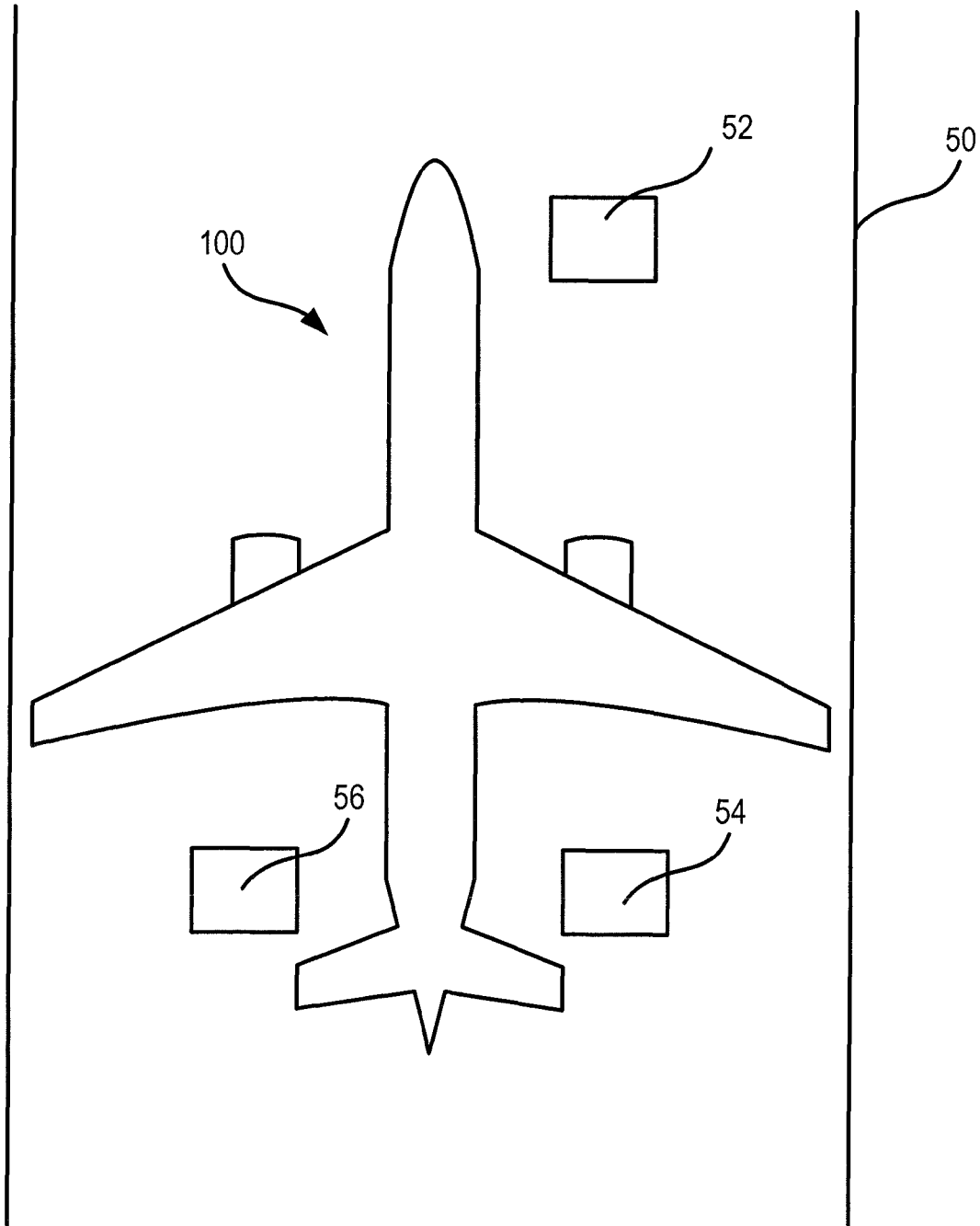


FIG. 2

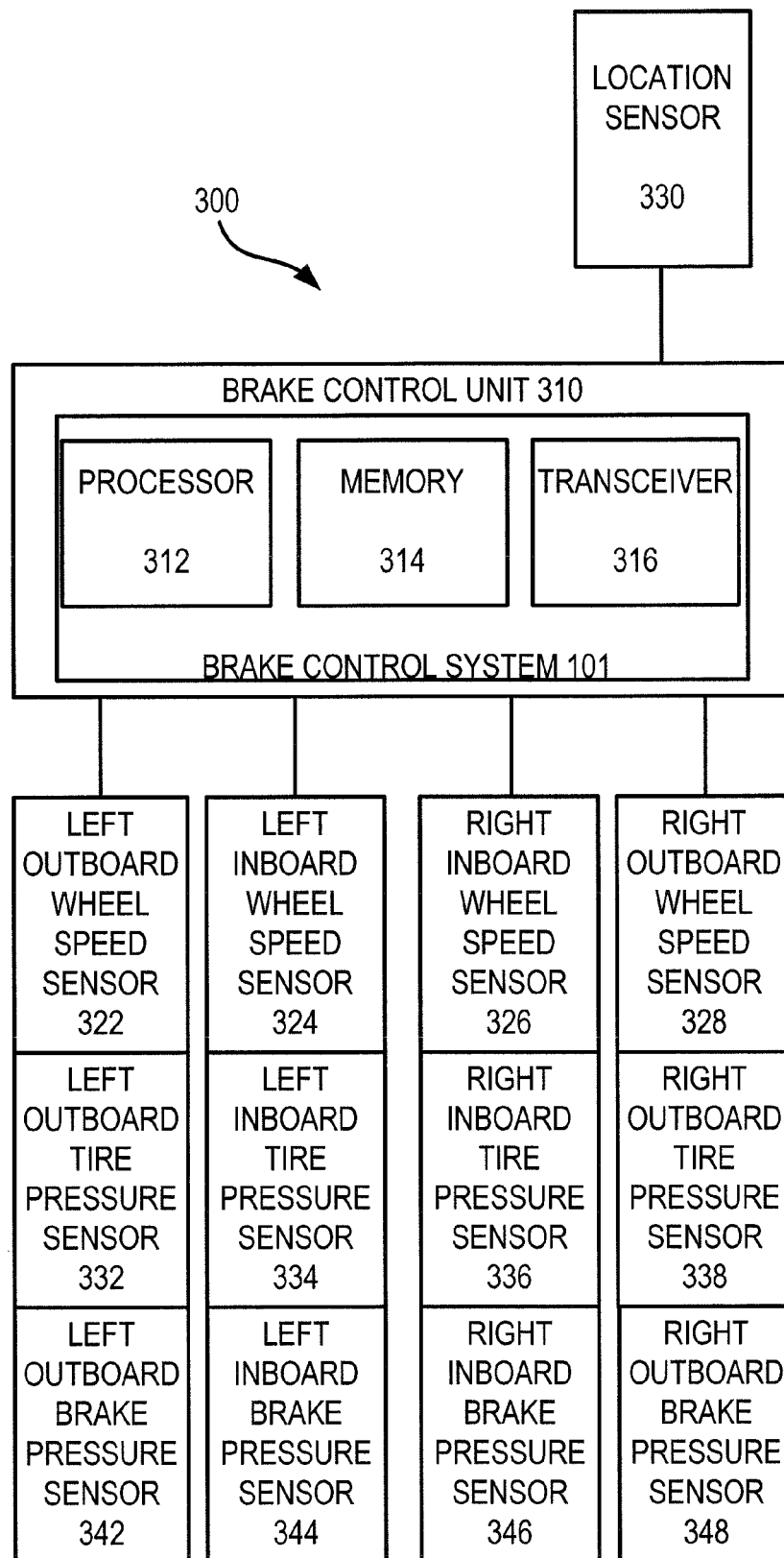


FIG. 3

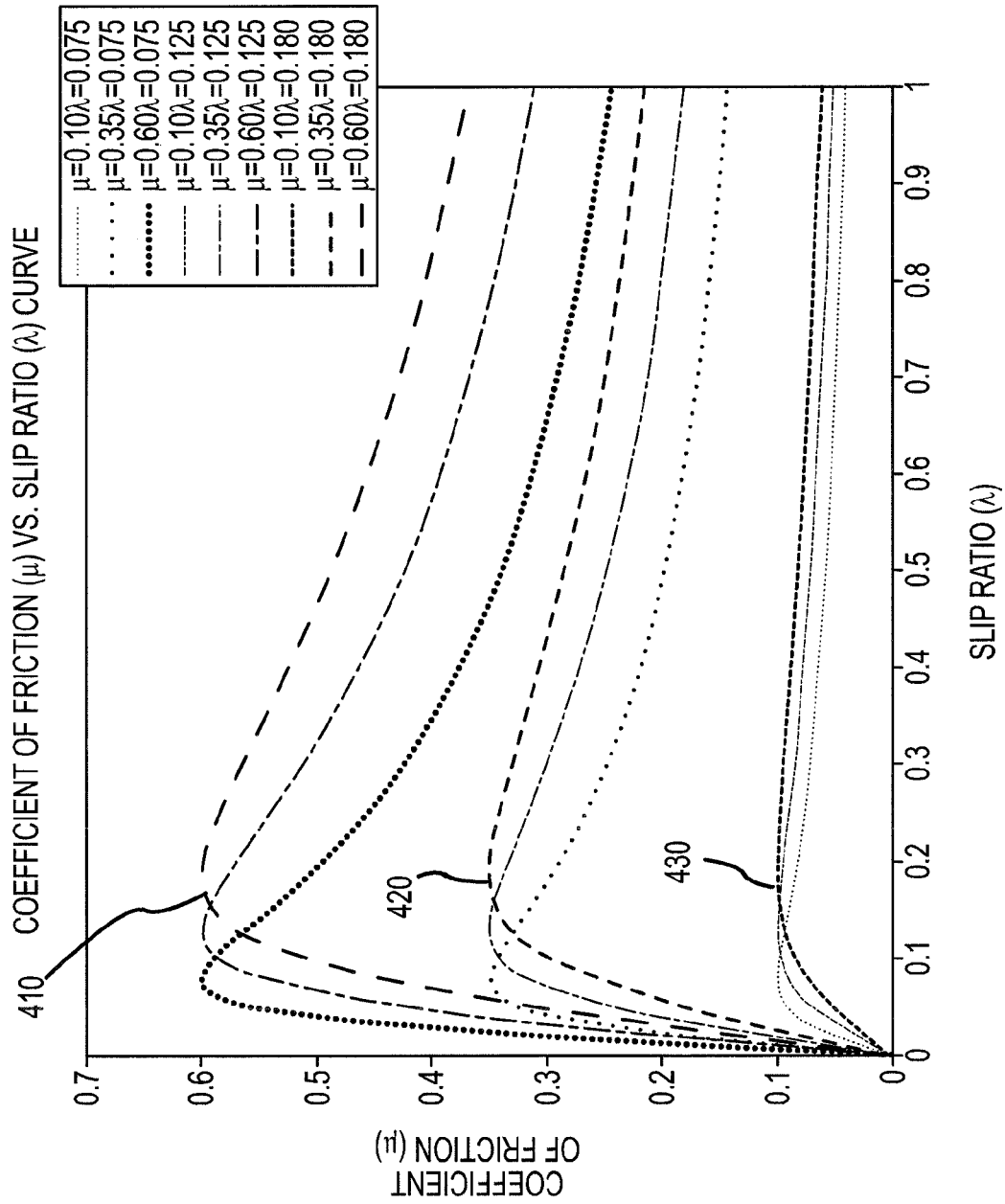
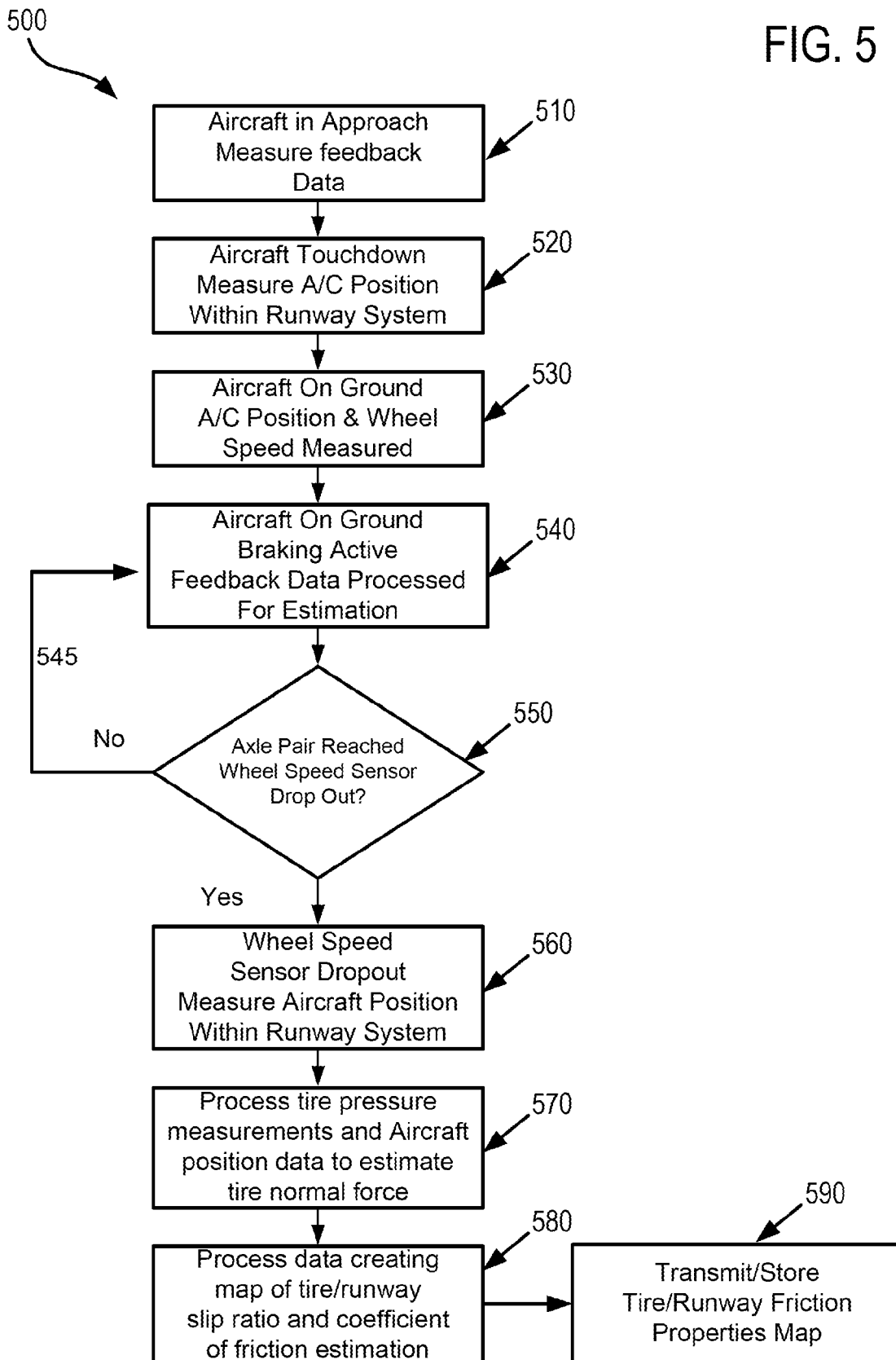


FIG. 4

FIG. 5



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BRAKE CONTROL SYSTEM COMPRISING TIRE/RUNWAY FRICTION PROPERTY ESTIMATION MAPPING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of, claims priority to and the benefit of, U.S. Ser. No. 13/935,137 filed Jul. 3, 2013, entitled "BRAKE CONTROL SYSTEM COMPRISING RUNWAY FRICTION PROPERTY ESTIMATION MAPPING," which is incorporated herein by reference in its entirety.

FIELD

The present disclosure relates to brake control systems, and more particularly, to a system for estimation of the tire/runway interface friction properties for aircraft.

BACKGROUND

Aircraft landing gear and aircraft wheels are typically equipped with brakes in order to stop an aircraft after landing or during a rejected take-off braking stop. Generally, a braked wheel can be described as experiencing one of four conditions; unbraked (synchronous speed), braked but not skidding (slip velocity less than critical value), skidding (slip velocity greater than critical value), or fully locked. Historically, prior to landing, having prior knowledge of various runway conditions was not possible. Brake control systems expend time to assess and enact operation. This time to assess braking conditions and change performance result in a reduction in braking performance and the potential increase to stop distances.

SUMMARY

A system and method for determining tire/runway interface friction properties related to aircraft braking assessed during braking events is disclosed herein. In various embodiments, the system may include a method for estimating a coefficient of friction and the slip ratio peak. The slip ratio may be the quotient resulting from the division of the slip velocity and translational axle speed. The slip ratio peak may represent the location (in terms of speed) of the peak coefficient of friction associated with a portion of a runway. This method may comprise estimating a wheel reference speed for a first braked wheel of an aircraft. Wheel reference speeds may be estimated using the measured wheel speed. This method may comprise measuring the first instantaneous wheel speed for the first braked wheel of the aircraft. Additional measurements may be made on any of the braked wheel components. This method may comprise determining a slip ratio of the first braked wheel. This method may comprise estimating a weight of an aircraft associated with the first braked wheel. This method may comprise mapping position data to the measured values. This method may comprise determining/estimating the coefficient of friction associated with various locations along the portion of the runway.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the present disclosure is particularly pointed out and distinctly claimed in the concluding portion of the specification. A more complete understanding of the present disclosure, however, may best be obtained by refer-

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ring to the detailed description and claims when considered in connection with the drawing figures, wherein like numerals denote like elements.

FIG. 1 illustrates, in accordance with various embodiments, a front view of an aircraft on a runway;

FIG. 2 illustrates, in accordance with various embodiments, a top view of an aircraft on a runway;

FIG. 3 illustrates, in accordance with various embodiments, a block diagram of a brake control unit;

FIG. 4 illustrates, in accordance with various embodiments, a simplified graph depicting coefficient of friction vs. slip ratio curve; and

FIG. 5 illustrates, in accordance with various embodiments, a method for exploiting on ground wheel braking for estimation of a coefficient of friction vs. slip ratio curve.

DETAILED DESCRIPTION

The detailed description of exemplary embodiments herein makes reference to the accompanying drawings, which show exemplary embodiments by way of illustration and their best mode. While these exemplary embodiments are described in sufficient detail to enable those skilled in the art to practice the disclosure, it should be understood that other embodiments may be realized and that logical, chemical, and mechanical changes may be made without departing from the spirit and scope of the disclosure. Thus, the detailed description herein is presented for purposes of illustration only and not of limitation. For example, the steps recited in any of the method or process descriptions may be executed in any order and are not necessarily limited to the order presented. Furthermore, any reference to singular includes plural embodiments, and any reference to more than one component or step may include a singular embodiment or step. Also, any reference to attached, fixed, connected or the like may include permanent, removable, temporary, partial, full and/or any other possible attachment option. Additionally, any reference to without contact (or similar phrases) may also include reduced contact or minimal contact.

In general, the tire, wheel, brake rotors and axle rotate together. The opposite of a skid event is the condition where the tire, wheel, etc., rotate freely at a speed equivalent to the translational axle speed. This equivalent speed without any deceleration is referred to as the synchronous wheel speed. As brakes are applied torque is generated which slows the rotational speed. This causes the wheel to rotate at a speed slower than the synchronous speed. This difference between synchronous speed and equivalent braked speed represents the slip velocity. As the slip velocity or difference increases the tire drag force created at the tire/runway interface increases causing the aircraft to decelerate. This drag force increases until slip velocity reaches a value dependent on tire/runway conditions. As slip velocity increases beyond this value drag force decreases. Thus, the goal of efficient antiskid control is to maintain operation near this critical slip velocity corresponding to the maximum drag force.

According to various embodiments, a map and/or a portion of a map may be produced based on substantially real-time information regarding the runway characteristics for use during a landing event. This information may include slip ratio and co-efficient of friction and/or the slip ratio peak information according to position, such as according to various positions along runway 50 at various times (see FIGS. 1 and 2).

According to various embodiments, a brake control system 101 (described in greater detail in FIG. 3) may be configured to continuously assess tire/runway 50 friction properties, detect the onset of wheel skids, and control brake torque to

achieve efficient and smooth braking performance. Thus, brake control system **101** may utilize an algorithm, along with substantially real-time measured values to assist with controlling brake torque to achieve efficient and smooth braking performance. A history of wheel speed information, such as wheel speed information associated with one or more landing event, may also be used to iteratively estimate tire/runway **50** friction properties.

Referring to FIG. **1**, a front view of an aircraft **100** on runway **50** is illustrated according to various embodiments. Aircraft **100** may comprise landing gear including left main landing gear (“LMLG”) **110**, nose landing gear (“NLG”) **120**, and right main landing gear (“RMLG”) **130**. Though a t-gear type landing gear aircraft is depicted, it should be appreciated that the concepts described herein are applicable to aircraft having multiple axle pairs per gear and aircraft with more than two gears. Each gear may comprise two wheels. For example, RMLG **130** comprises right outboard wheel **132** and right inboard wheel **134**. However, in various embodiments, aircraft **100** may comprise any number of gears and each gear may comprise any number of wheels. Additionally the concepts disclosed herein variously apply to two wheel aircraft (e.g. one wheel for each main landing gear).

Referring to FIG. **2**, a top view of aircraft **100** on runway **50** is illustrated according to various embodiments. Thus, in various embodiments, one or more aircraft **100** wheels may be in contact with the pavement of runway **50**. Different coefficients of friction of runway **50** at various positions, such as positions **52**, **54**, and **56**, may cause the wheels of aircraft **100** to spin up at varying rates. In various embodiments, the wheels associated with LMLG **110** may spin up faster than the wheels associated with RMLG **130** due to a higher coefficient of friction for runway **50** at one position versus another position. In various embodiments, runway **50** may comprise multiple contaminants, such as ice, mud, oil, fuel, water and/or snow, each of which may affect a measured/estimated coefficient of friction at various positions. The measured/estimated coefficient of friction at various positions along runway **50** may be time-specific. For instance, the measured/estimated coefficient of friction at various locations may change based on conditions over time.

Referring to FIG. **3**, a system **300** for detecting on ground characteristics is illustrated according to various embodiments. System **300** may comprise a brake control unit (BCU) **310**. A brake control system **101** may be a subsystem of brake control unit **310**. Brake control system **101** may be in communication with brake control unit **310**. Brake control system **101** may be communicatively coupled to left outboard wheel speed sensor **322**, left inboard wheel speed sensor **324**, right inboard wheel speed sensor **326** and right outboard wheel speed sensor **328**. Brake control system **101** may comprise a left outboard tire pressure sensor **332**, left inboard tire pressure sensor **334**, right inboard tire pressure sensor **336**, and right outboard tire pressure sensor **338**. Tire pressure measurements may be used to infer a weight and force present on the tires at various times/locations. The tire pressure measurement may allow for an estimation of a tire spring constant. For instance, the tire pressure helps to identify a spring constant. When coupled with a tire radius information and position data a force may be estimated if not directly measured. For instance, tire pressure coupled with the tire radius derived from the distance between an aircraft touchdown and wheel speed sensor drop out positions allow for normal force estimation. The elimination of the tire pressure measurement does not prevent this estimation but limits its fidelity.

A location sensor **330** may be coupled to brake control system **101** and/or brake control unit **310**. Location sensor

330 may be a GPS unit/receiver. Location sensor **330** may be configured to determine position of aircraft **100** at each braked wheel location. Brake control unit **310** may be coupled to a transceiver **316**. The various components may be electronically coupled. In various embodiments, the various components may communicate via wireless and/or wired communications. For example, wheel speed sensors **322**, **324**, **326**, **328** may transmit, via wired and/or wireless transmission, wheel speed measurements to brake control system **101** and in turn to brake control unit **310**. The wheel speed sensors, pressure sensor and tire pressure sensors may be hard wired to BCU **310**. Transceiver **316** may transmit the slip ratio vs. position data and the coefficient of friction vs. position data to a central data base/processing computer. This central data base/processing computer may be a collection of each air plane's friction map for processing and/or aggregating.

Brake control unit **310** and/or brake control system **101** may comprise a computing device (e.g., processor **312**) and an associated memory **314**. Memory **314** may comprise an article of manufacture including a tangible, non-transitory computer-readable storage medium having instructions stored thereon that, in response to execution by a computing device (e.g., processor **312**), cause the computing device to perform various methods.

Wheel speed sensors **322**, **324**, **326**, **328** may measure a wheel speed. Wheel speed sensors **322**, **324**, **326**, **328** may comprise any device capable of measuring a wheel speed. For example, in various embodiments, wheel speed sensors **322**, **324**, **326**, **328** may comprise electromagnetic transducers and/or fiber optic transducers. In various embodiments, the wheel speed sensors may comprise an AC sensor which uses a magnet surrounded by a pickup coil in an axle of the landing gear. In various embodiments, wheel speed sensors **322**, **324**, **326**, **328** may comprise a DC sensor which may comprise a permanent magnet direct current generator, which outputs a voltage proportional to a rotational speed of its armature. Additionally, wheel speed sensors **322**, **324**, **326**, **328** may detect a change in a rate of deceleration of the wheels. The processing of wheel speed to produce acceleration is primarily performed by a brake control algorithm (BCA) contained within the brake control unit **310**. The BCA processes the wheel speed, wheel acceleration, and brake pressure (hydraulic brake) or electric actuator (electric brakes) to calculate the braking pressure/force best suited for the most desirable braking. This may reduce a skid to recover a more efficient braking or short stopping distance. The resulting braking commands (e.g. pressure or force) may tend to minimize skids and cause braking commands to achieve efficient brake operation and short aircraft stopping distance. The resulting braking commands may correspond to gentle braking conditions to achieve smooth braking.

The wheel speed may be the actual measured speed of the wheel. In various embodiments, each wheel on aircraft **100** may be equipped with a wheel speed sensor **322**, **324**, **326**, **328**. However, in various embodiments, aircraft **100** may comprise a wheel speed sensor on any braked wheel. Wheel speed sensors **322**, **324**, **326**, **328** may transmit (such as via a wired coupling) the wheel speed data to brake control unit **310**. Brake control unit **310** may calculate a reference wheel speed for each wheel. The reference wheel speed may be the over ground speed that the wheel would be travelling if the wheel were rolling without slipping. For example, if wheel speed sensor **322**, **324**, **326**, **328** measures a wheel speed of 10 radians per second for a wheel with a radius of 1 meter, brake control unit **310** may calculate a reference wheel speed of 10 meters per second. During spin up and subsequent braking, wheels may be at least partially slipping. Thus, the wheel

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reference speed may be different from the actual speed of aircraft **100** during spin up and braking events. The BCA may process wheel speed measurements which results in a wheel reference speed. The wheel reference speed may be set equal to the wheel speed during initial portions of a landing stop. The BCA wheel reference calculations are designed to estimate the aircraft speed rejecting the wheel speed effects of skidding, spin ups, and/or the like. A skidding or slipping wheel (after the key threshold wheel speed threshold) produces less drag force. Thus, the aircraft is decelerated less but the wheel reference reflects the aircraft speed not the wheel speed. Wheel reference speeds are estimation of aircraft speed and separate more from the wheel speed as a skid grows deeper.

Processor **312** may map the measured wheel speed measurements to aircraft **100** position data on runway **50** to determine an estimate of the coefficient of friction for portions of runway **50** and/or the slip ratio of the wheel. A skid may occur as the applied brake torque exceeds the available spin up torque created from the tire/runway interface friction. Processor **312** may utilize a measured wheel speed, calculated acceleration, wheel reference and tire normal force estimation mapped to aircraft **100** position data on the runway **50** to determine an estimate of the coefficient of friction and/or the slip ratio as a function of position. In response to landings that involve the anti-skid function, peak wheel accelerations may be used to estimate a peak coefficient of friction (see FIG. **4**). The wheel speed and wheel reference may be used to estimate slip ratio. The peak wheel acceleration and tire normal force may be used to estimate the coefficient of friction. The slip ratio value corresponding to the peak coefficient of friction may define the peak slip ratio. In response to landings that do not involve the anti-skid function, measured wheel speed, calculated acceleration, wheel reference, and tire normal force estimation may be used to estimate a lower bound of the wheel slip value and/or coefficient of friction.

In response to a low speed threshold (such as wheel speed sensor dropout (about 10 kts, about 18.52 Km/hr)) an estimate of aircraft **100** weight is obtained and the instantaneous runway **50** friction property may be calculated for each of the braked wheels as a function of aircraft **100** position data (previously recorded, such as by location sensor **330**). A low speed threshold may involve the aircraft being free from forces which would alter the tire normal forces. Estimating the weight of the aircraft may involve determining a tire pressure of a tire of the first braked wheel and calculating the weight of the aircraft based on the determined change tire pressure from a known reference value. This is coupled with the distance between the aircraft touchdown position and low speed threshold condition position. The tire pressure sensor helps with the identification of the spring constant to associate with the tire and the distance and assists the identification of the tire radius. Aircraft position may be ascertained more than once after wheel speed sensor drop out to verify tire radius. This may assist with the estimation the tire normal force which is used with calculate the friction property data. This calculation may be done "after-the-fact" as an accurate aircraft **100** weight measurement cannot generally be obtained during the landing due to transient lift and aircraft pitching due to braking. This may include but is not limited to the aircraft pitching which may occur during antiskid cycling. For instance, at certain speeds, lift from the wings may substantially affect a weight measurement. Thus, this after-the-fact calculation may be made in response to aircraft **100** traveling at a speed where there is no lift adversely affecting the calculation.

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Runway **50** touchdown and/or a low speed threshold location data may be obtained from a position/location sensor **330**, such as a GPS unit/receiver. The positioning data may be used in conjunction with a measured number of wheel rotations for each wheel. The wheel rotation count and the wheel radius may be used to estimate the absolute runway **50** positions; which, in turn, have associated slip and friction values (which may be calculated/extrapolated from the measured wheel speed, calculated acceleration, wheel reference and tire normal force estimation at those locations).

This information may be transmitted to a system external to aircraft **100** and made available for additional aircraft landing on runway **50**. The findings of the actual location, e.g. portions of runway **50** traveled by aircraft **100**, during a landing event, at various intervals may be aggregated with measured results of other aircraft having brake control system **101** to develop an expanded knowledge of runway **50** and its characteristics for a period of time. Brake control system **101** may create a moving average of the data to identify longer-term trends of the coefficient of friction and/or the slip ratio as a function of position. This expanded knowledge of runway **50** characteristics may be communicated to additional components of aircraft **100** and/or other aircraft in the vicinity or expected to be in the vicinity so that appropriate action may be taken.

In operation, in response to a touchdown associated with a landing on runway **50**, wheel speed information is collected. Initially, each wheel is subject to a spin up condition, to bring the wheels up from substantially stationary to a rolling speed which is the same as aircraft **100** during landing. During this period, a touchdown protection phase is enacted so that no brakes are applied. In response to a wheel speed spin up and/or touchdown, a wheel reference value measurement is made. A wheel reference value may be an estimate of aircraft **100** speed measured at each wheel. The reference speed may be updated at any suitable time. For instance the reference speed may be continuously updated throughout the braking event and continues until low speed threshold condition. Thus, aircraft **100** equivalent speed which is the instantaneous wheel speed and wheel reference data may be initial quantities for brake control system **101**. Initially these values should be substantially equivalent. In response to applying a brake, a drag force is generated. In turn, these values (e.g. the instantaneous wheel speed and the wheel reference value) separate. The brake pressure from sensors **342**, **344**, **346**, **348** and/or the tire pressure from sensors **332**, **334**, **336**, **338** may be measured at this time. Based on the friction generated, the rotation of each wheel relative to aircraft **100** speed is decreased. An aircraft reference speed is calculated/estimated and is calculated as a weighted combination of the individual wheel reference speeds.

Referring to FIG. **4**, a graph depicting a coefficient of friction and/or the slip ratio according to various embodiments is presented. This data plotted at various times and/or positions may yield information regarding conditions of the runway and capacities of the braking system associated with those conditions. Varied runway conditions will affect the data. For instance, dry runway conditions may be associated with peak **410**. Wet runway conditions may be associated with peak **420**. Icy runway conditions may be associated with peak **430**.

In response to measured brake pressure or brake actuator force torque generated may be estimated. Brake pressure may be either increasing or decreasing. In response to the slip exceeding the key peak value the increasing brake pressure will result in decreasing drag force. A measured acceleration maximum during a period where aircraft **100** is generating

wheel slips corresponds to the peak slip ratio as related in the coefficient of friction vs. slip relationship. Thus, in response to maximum accelerations being measured, an estimate of the slip ratio curve and the value of coefficient of friction associated with the slip ratio may be gleaned.

In response to this reduction in speed, a peak of a new slip curve may be crossed. Each peak, **410**, **420**, **430** may correspond to a peak acceleration. In a landing, constantly cycling will create multiple estimated peaks for the coefficient of friction vs. slip ratio curve, and the threshold may be crossed multiple times and establish a new peaks at various plotted locations.

The peak of the new slip curve may be a peak friction point given the slip ratio. In response to a braking stop where there is no skidding, (e.g. no anti-skid system event), a lower bound to a slip ratio, and/or a lower bound for the coefficient of friction may be established. This lower bound may establish that the wheel is at least capable of this much friction without a slip event. This information may be exploited by aircraft **100**.

Referring to FIG. **5**, a process **500** for detecting an on ground characteristic is illustrated according to various embodiments. As aircraft **100** prepares for landing, brake control unit **310** may be in approach mode and measure feedback data (Step **510**). In response to aircraft **100** landing the wheels rotations may be spun up to aircraft **100** speed (Step **520**). Aircraft position may be measured (Step **520**). Brake control unit **310** may collect additional data in response to the landing. On ground position of the aircraft and/or wheel speed may be measured (Step **530**). This may be done at any time and/or at any interval of time. On ground braking active data feedback may be processed for estimation (Step **540**). A determination whether the axle pair has reached a wheel speed sensor drop out may be made. (Step **550**). If not, return to step **540**. (Step **545**).

The low speed threshold (ex. wheel speed sensor drop out speed) sensor may be associated with the aircraft position within the runway system (Step **560**). The tire pressure measurements and aircraft position data may be used to estimate tire normal force (Step **570**). Data for creating a map of tire/runway slip ratio and coefficient of friction estimation may be processed (Step **580**). The tire/runway friction properties may be transmitted and/or stored by the system (Step **590**).

The reference wheel speed and the instantaneous wheel speed will begin to separate as the brakes are applied and friction is produced. These values may be compared by processor **312** utilizing one or more algorithms to determine a slip ratio as a function of aircraft position (Step **560**). Acceleration maximums of the wheels may be noted as part of this process **500**. A coefficient of friction may be determined/estimated as a function of position. These measured/estimated coefficient of friction values may be mapped to relevant portions of runway **50** (Step **580**). Measured values and/or determinations may be stored to memory **314** and/or transmitted by transceiver **316**. Note, the systems disclosed herein are applicable to braking during landing and/or during a rejected take-off braking stop.

Benefits, other advantages, and solutions to problems have been described herein with regard to specific embodiments. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may

cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements of the inventions. The scope of the inventions is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." Moreover, where a phrase similar to "at least one of A, B, or C" is used in the claims, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B and C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C. Different cross-hatching is used throughout the figures to denote different parts but not necessarily to denote the same or different materials.

Systems, methods and apparatus are provided herein. In the detailed description herein, references to "one embodiment", "an embodiment", "an example embodiment", etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. After reading the description, it will be apparent to one skilled in the relevant art(s) how to implement the disclosure in alternative embodiments.

The term "coefficient of friction" as used herein may refer to the ratio of the force that maintains contact between an object and a surface and the frictional force that resists the motion of the object. The frictional force may be equal to the coefficient of friction multiplied by the normal force on the surface. Slip ratio as used here may refer to a means of calculating and expressing the locking status of a wheel. Slip Ratio % = [(Vehicle Speed - Wheel Speed) / Vehicle Speed] x 100.

Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112, sixth paragraph, unless the element is expressly recited using the phrase "means for." As used herein, the terms "comprises", "comprising", or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

What is claimed is:

1. A method for determining coefficients of friction along a portion of a runway comprising:

receiving, by a brake control unit, a first axle reference speed for a braked wheel of an aircraft;
establishing, by the brake control unit, a wheel reference speed for the braked wheel of the aircraft;
determining, by the brake control unit, a slip ratio of the braked wheel, wherein a lower bound of wheel slip values are calculated in response to a braking stop comprising no anti-skid system event;

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estimating, by the brake control unit, a weight of the aircraft associated with the first braked wheel;
 mapping, by the brake control unit, position data to the measured values; and
 estimating, by the brake control unit, coefficients of friction associated with locations along the portion of the runway.

2. The method of claim 1, wherein the establishing the wheel reference speed of the braked wheel comprises measuring a wheel speed of a wheel.

3. The method of claim 2, further comprising transmitting the first axle reference speed for the braked wheel of the aircraft from a wheel speed sensor to the brake control unit.

4. The method of claim 1, wherein the estimating the weight of the aircraft comprises determining a tire pressure of a tire of the braked wheel, and calculating the weight of the aircraft based on the determined change tire pressure from a known reference value.

5. The method of claim 1, further comprising calculating position data from a location sensor.

6. The method of claim 5, wherein the location sensor is a global positioning unit.

7. The method of claim 1, further comprising estimating, by the brake control unit, a slip ratio peak associated with locations along the runway.

8. The method of claim 1, further comprising utilizing a low speed threshold condition to reduce tire normal force disturbances.

9. The method of claim 1, further comprising transmitting the determined coefficient of friction associated with the portion of the runway to a central processor.

10. The method of claim 1, further comprising aggregating determined coefficient of friction information from additional aircraft to establish an expanded mapping of the coefficient of friction associated with the runway.

11. The method of claim 1, wherein the portion of the runway is associated with a path of travel of the aircraft.

12. The method of claim 1, wherein an anti-skid system event associated with the aircraft is used to create estimations of the runway friction properties.

13. The method of claim 12, wherein peak wheel accelerations are used to estimate peak slip ratio values.

14. The method of claim 1, wherein the determined coefficients of friction associated with the locations along the portion of the runway are exploited to detect an onset of a wheel skid.

15. The method of claim 1, wherein the determined coefficients of friction associated with the locations along the portion of the runway are exploited to achieve at least one of smooth and efficient braking conditions.

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16. An article of manufacture including a non-transitory, tangible computer readable medium having instructions stored thereon that, in response to execution by a computing device, cause the computing device to perform operations comprising:

establishing, by the computing device, a first wheel reference speed for a first braked wheel of an aircraft;
 measuring, by the computing device, a first wheel instantaneous speed for the first braked wheel of the aircraft;
 determining, by the computing device, a slip ratio of the first braked wheel, wherein a lower bound of wheel slip values are calculated in response to a braking stop comprising no anti-skid system event;
 estimating, by the computing device, a weight of the aircraft associated with the first braked wheel;
 mapping, by the computing device, position data to the measured values; and
 estimating, by the computing device, at least one of the coefficient of friction and slip ratio peak associated with locations along a portion of a runway.

17. The article of manufacture of claim 16, further comprising transmitting, by the computing device, the determined coefficient of friction associated with the portion of the runway to a central processor.

18. The article of manufacture of claim 16, further comprising calculating position data from a location sensor.

19. A system comprising:

a tangible, non-transitory memory communicating with a processor, the tangible, non-transitory memory having instructions stored thereon that, in response to execution by the processor, cause the processor to perform operations comprising:

establishing, by the processor, a first wheel reference speed for a first braked wheel of an aircraft;
 measuring, by the processor, a first wheel instantaneous speed for the first braked wheel of the aircraft;
 determining, by the processor, a slip ratio of the first braked wheel, wherein a lower bound of wheel slip values are calculated in response to a braking stop comprising no anti-skid system event;
 estimating, by the processor, a weight of the aircraft associated with the first braked wheel;
 mapping, by the processor, position data to the measured values; and

estimating, by the processor, at least one of a coefficient of friction and slip ratio peak associated with locations along a portion of a runway.

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